

ENERGY-EFFICIENT LIGHTING POLICIES AND PROGRAMS FROM THE UNITED STATES GOVERNMENT

Evan Mills, Ph.D.

Assistant Director, Center for Building Science, Lawrence Berkeley Laboratory

MS 90-3058, Berkeley, CA 94720, USA

tel: +1.510.486-6784 • fax: +1.510.486-5394 • e-mail: emills@lbl.gov.

Proceedings of the 2nd International Lighting Conference, May 22–27 1995 Suzdal, Russia

Abstract

The U.S. government is active in promoting energy-efficient lighting, complementing efforts of the private sector. The current cost of lighting energy in the U.S. is about \$36 billion per year, and this amount could be reduced by half or more with cost-effective investments in improved energy efficiency. Current government activities helping to achieve these savings include:

- Providing objective information on technical options and cost-effectiveness
- Research and development (lamps, fixtures, design tools, human factors)
- Supporting electric utility conservation programs and planning
- Product labeling and rating
- Improving lighting efficiency in government-owned buildings
- Legislation of mandatory efficiency standards
- Offering voluntary programs and incentives

This paper provides examples of each of these activities. Examples of concerned government bodies include the Department of Energy (DOE), Environmental Protection Agency (EPA), Federal Trade Commission (FTC), and the Department of Housing and Urban Development (HUD). In addition, several of the largest government units (Department of Defense, DOE, Veterans Administration, Postal Service, and Government Services Administration) operate in-house energy management programs that include considerable lighting retrofit activities. Presidents Reagan and Clinton has played an essential role in setting the stage with the Climate Change Action Plan and legislation such as the Energy Policy Act of 1992.

Introduction

The United States spends nearly \$500 billion each year on energy. Of this total, nearly 10% (\$36 billion, 500 billion kilowatt-hours) is spent for lighting energy. About 20% of all electricity in the U.S. is used for lighting. The resulting costs and environmental impacts are considerable when compared to lighting energy use in other countries (Figures 1 and 2). The total cost could be reduced considerably—50

to 80% according to most studies—if more money was spent on efficient technology. Market forces (energy prices, consumer information) have helped to further the process of efficiency improvements, but many opportunities have still not been taken.

U.S. Lighting Costs and Pollution in Perspective

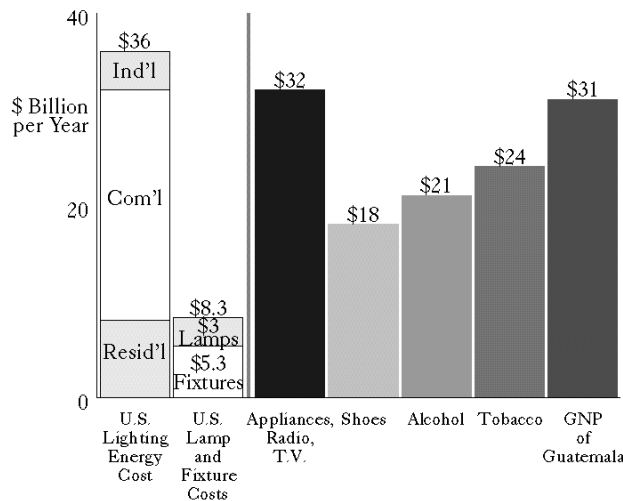


Figure 1

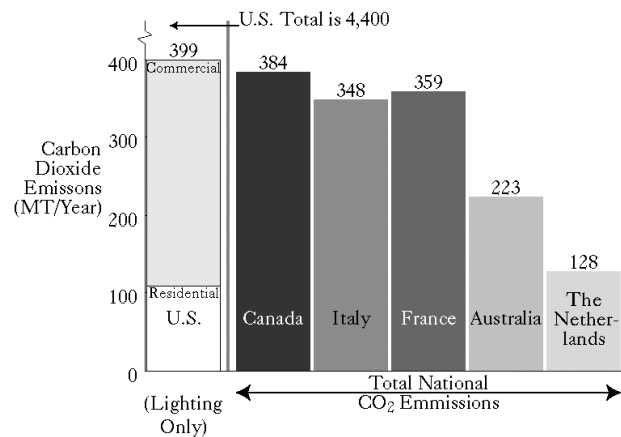


Figure 2

The U.S. example shows that intensive government intervention is required in order to maximize energy efficiency, *even in a free-market economy*. The main reason for this is that there are a significant number of market failures that interfere with progress towards an optimally efficient lighting system. These include (a) energy prices that do not reflect true economic costs, (b) environmental and other non-monetary costs not reflected in the price of energy, (c) imperfect consumer information and access to efficient technologies, (d) lack of capital with which to make efficiency investments, (e) split incentives, e.g. where owners of buildings pay for equipment and renters of buildings pay the energy bills, and (f) industry reluctance to pursue innovative research and development or to commercialize new products when the potential market demand for those products is unknown.

Technology R&D

Official responsibility for basic research and development on energy-efficient lighting in the United States is the responsibility of the U.S. Department of Energy. Lawrence Berkeley Laboratory (LBL) is the primary DOE site at which this research is carried out. Following are highlights of DOE's R&D program.

- **Electronic Ballast**—The electronic ballast is a technology that improves the efficiency of fluorescent lighting systems by up to 30% and enhances quality and flexibility. During the incubation of the electronic ballast industry in the late 1970s, LBL contracted with three small companies to produce early commercial models. The intent of this early effort was to accelerate the availability of electronic ballasts by demonstrating their energy efficiency and reliability in typical building environments (Verderber et al., 1979 and 1982). After delivery to LBL for testing to assure compliance with specifications, the ballasts were installed at a demonstration site in a local utility office (PG&E) in San Francisco. The results of these early demonstrations were widely publicized at technical and trade conferences. Later work at LBL helped to improve the quality of the ballasts and validate the potential for energy savings from dimming. The current market share of electronic ballasts is 23% of all ballasts sold.
- **Advanced light sources**—The primary focus is on developing the sulfur lamp, an electrodeless, very-high-frequency lamp which uses sulfur rather than mercury as the light-producing element. High- and low-power versions are under development, with a target system efficacy of approximately 130 lumens/watt. Savings of 30-50% are anticipated, in comparison to mercury or metal halide light sources. (See Figure 3)
- **Light guides**—The success of the sulfur lamp and other high-intensity sources in indoor environments depends on new luminaire systems, notably light guides designed to manage the distribution of light from artificial light sources and, potentially, daylight. Areas of emphasis include use of new materials and more advanced optical, mechanical, electronic, and thermodynamic designs (Siminovitch 1994). Demonstrations are already underway at the USDOE headquarters and the Smithsonian Air and Space Museum. This work builds on the tradition of research on “Hollow Light Guides” started in Russia in the 1960s.
- **Compact fluorescent thermal management**—It is well known



Figure 3: LBL researcher examines prototype sulfur lamp.

that non-amalgam CFLs suffer severe light output reductions when operated in a base-down position. Up to 25% reductions occur because mercury settles into the hot tubulation within the base of the lamp. Simple conductive cooling strategies developed at LBL virtually eliminate this problem, at a cost of only a few pennies per lamp (see Figures 4–6).

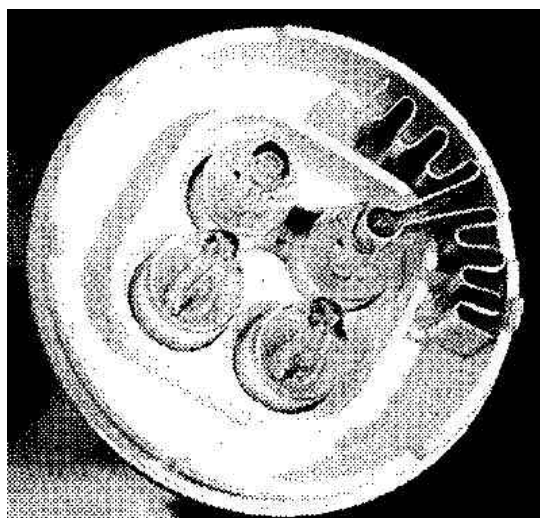


Figure 4: Rippled internal thermal bridge at the base of an open CFL. A small copper strip attached to the glass tabulation rapidly conducts heat away from the lamp.

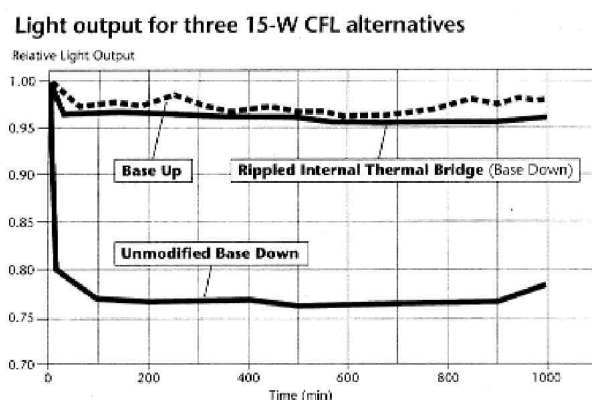


Figure 5: The base-up alternative produces almost 100% of the rated light output. The light output from the base-down CFL decreases by nearly 25% after a few minutes of operation. However by adding a thermal bridge (see Figure 3), the performance of the base-down CFL improves dramatically. (In all three cases, light output rises to 1.00 during the first three minutes.

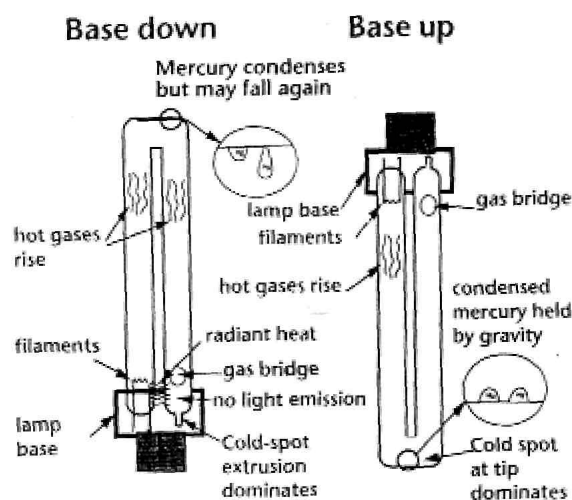


Figure 6: In a base-down CFL, excess mercury drips from the cold spot into the glass tubulation in the base where it is re-vaporized. This causes 20-25% less light output than provided by the base-up lamp.

- CFL fixtures—Pioneering work has shown how to modify CFL fixtures to eliminate the 15-20% light losses that can result from excessive heat buildup within the fixture. The research here identified a variety of design solutions, several of which have been adopted by commercial manufacturers (Siminovitch et al., 1990). (See Figure 7)

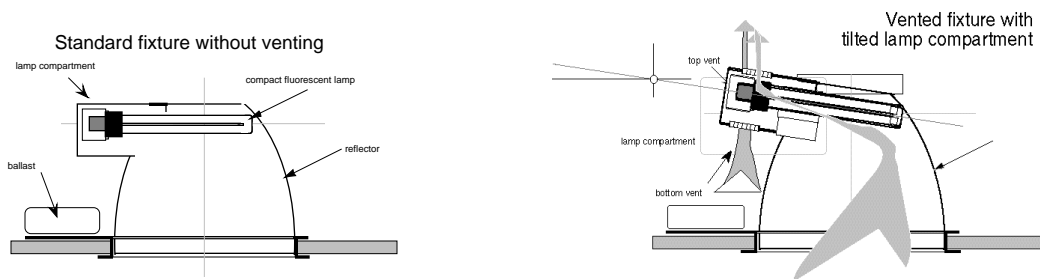


Figure 7: Allowing for passive ventilation, and tilting lamp to keep excess mercury away from hot lamp electronics, increases fixture light output by about 20%.

- **Daylighting**—There is a variety of research on the performance of advanced glazing and architectural systems for maximizing the amount of useful daylight in indoor environments. Analyses have quantified the energy savings achievable with dimmable ballasts and automated daylight sensor control systems. These demonstrations documented a savings potential of greater than 50% in typical office buildings (Rubinstein and Verderber 1990). (See Figure 8)

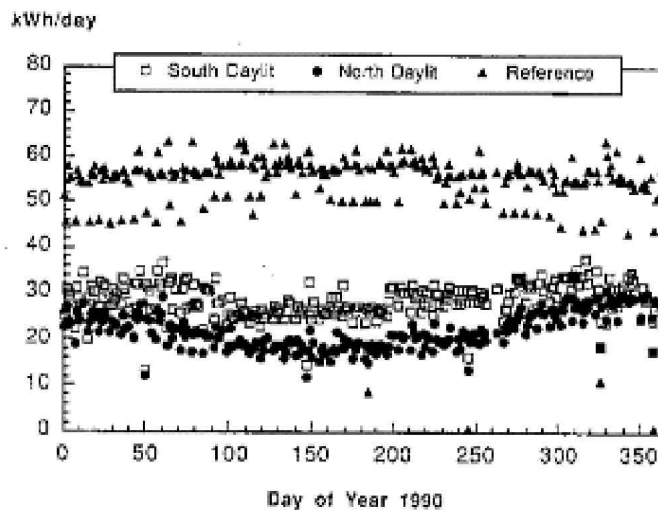


Figure 8: Lighting energy use on weekdays in south and north daylit zones of a real office building using integrated lighting controls compared to energy use in reference zone without controls

- **Visual Performance**—Fundamental research on human vision conducted by DOE indicates that lighting energy can be saved by using lamps with a spectral balance higher in the bluish range. Thus pupil size adjusts to assure that visual performance is maximized. Measuring a lamp’s light output in “pupil lumens,” which take into account the relative contributions of scotopic and photopic stimulation (rods and cones, respectively), could eventually lead to revised recommendations for lighting levels to meet visual needs while requiring less electricity (Berman 1992).

- Another project's aim is the analysis of the potential for light-emitting diodes to become sources of general illumination.

Design Tools

A key part of the DOE program concerns lighting design and analysis tools. This aims to provide new objective tools, available at no or low cost to potential users.

- The RADIANCE ray-tracing program can generate photo-realistic and photometrically accurate images of complex interiors, accounting for the contribution of daylight and electric light to the total luminous environment (Figure 9). RADIANCE can model specific light fixtures and daylighting technologies. DOE has been the primary supporter of Radiance. The Federal Aviation Administration is a recent supporter of this work, intending to use the tool in the design of better air traffic control towers (Ward 1994). (See Figure 9)



Figure 9: Two views of a proposed redesigned work station in the Old Executive Office Building in Washington DC. Redesign was done as part of the "Greening of the White House" project conducted by the DOE's Federal Energy Management Program. RADIANCE simulations show daylight conditions under an overcast sky (left) and night-time conditions with overhead fluorescent fixtures and task lights on the desktop.

- The DOE's Federal Energy Management Program (FEMP) has developed the Federal Lighting Expert System (FLEX) to help government facility managers choose cost-effective efficient lighting technologies.
- The SUPERLITE program is a mainframe and microcomputer program that calculates daylight illuminance distributions for complex room and light source geometries with tested accuracy (Selkowitz et al., 1982).
- The WINDOW program contains libraries of glazing materials, selective coatings, gas fills, and frame materials that can be used to simulate heat loss for window systems as well as total solar transmission, which contributes to daylighting (Fin-

layson et al., 1993). The program has recently been translated into Russian.

Public Buildings

One of the most powerful options available to government is to make its own buildings more efficient, providing “leadership by example”. The White House was recently the subject of comprehensive audits and retrofits, which included efficient fluorescent lighting upgrades, advanced controls, and daylighting. (See Figure 10)



Figure 10: At an Earth Day 1994 celebration, President Clinton extols the benefits of a compact fluorescent lamp, while a CFL production employee looks on. Also in attendance were Vice President Al Gore and eight cabinet members. (Photo by Marvin Jones, courtesy Osram Sylvania, Inc.)

- Most major public agencies have programs to improve energy efficiency in their own buildings. The U.S. Department of Energy, for example, operates 14,000 buildings and spends \$300 million/year on energy. They have been investing \$30 million per year in energy-efficiency upgrades, a significant fraction of which is for lighting (Greenberg et al., 1994).
- FEMP provides training to managers of government facilities, design assistance programs, advanced technology demonstrations, and other energy-related activities. FEMP has recently founded the Federal Energy Efficiency Fund (about \$8 million per year). The funds are distributed to small agencies that may not have specific funding for energy-saving projects to help them make energy efficiency improvements. A possible future FEMP project will involve making lighting efficiency improvements at the Gorbachov Foundation, located at the National Park Service’s Presidio in San Francisco, California.
- The Department of Housing and Urban Development (HUD) operates the national public housing program, which provides homes for nearly four million people (Ritschard et al. 1986). HUD conducts various energy-efficiency demonstration and financing programs, some of which are directed at lighting.

Efficiency Standards

Government (city, state, national) has the unique ability to establish lighting energy

standards, can be voluntary or mandatory, and can address specific technologies or total system energy performance. A national analysis showed a potential energy savings of 65% in commercial and residential buildings (equivalent to 450 BkWh, 78 GW, and a net present value of \$150 billion) (Atkinson et al., 1992). Figure 11 shows the results for the commercial buildings sector.

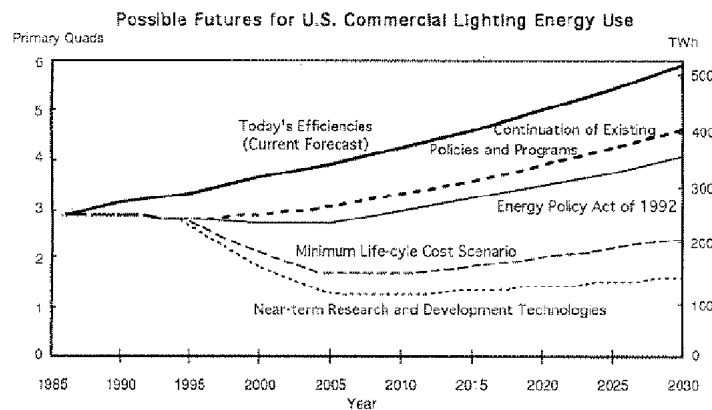


Figure 11

- A number of states (e.g. California) have adopted voluntary or mandatory lighting efficiency codes for new buildings. These are typically expressed in terms of annual lighting energy use (or lighting power density) per square meter. Different standards apply to different types of buildings (e.g. hospitals versus schools).
- Some cities have implemented codes that apply to existing residential or commercial buildings. When the buildings are sold, remodeled, or refinanced, certain energy saving options must be implemented.
- Fluorescent ballasts have been regulated in the U.S. since 1990. This has led to an approximately 10% energy savings over the standard core-and-coil ballasts.
- The Energy Policy Act of 1992 (Public Law 102-486) is a major piece of national legislation regulating lighting products. Its provisions include component performance standards, labeling, and building efficiency standards.
 - Standards for 4-foot, 2-foot, U-tube, 8-foot slimline, and 8-foot high-output fluorescent lamps specify CRI and efficacy, effectively ruling out the standard 38-mm (40-watt) lamps, and requiring reduced wattage (34-watt) lamps at a minimum.
 - Efficacy standards for common incandescent reflector lamps—traditional reflector lamps—were outlawed.
 - The Federal Trade Commission is required to implement a labeling program for general service incandescent and fluorescent lamps.
 - The act encouraged voluntary luminaire testing and information program to use labels, catalogs, trade publications, and other means.
 - Testing requirements for high-intensity discharge lamps and options for standards and labeling will be explored.

- Individual states must update their commercial building codes to meet or exceed the requirements of the ASHRAE/IES standard 90.1-1989, stipulating specific lighting power density limits (W/m²) for various types of buildings and tasks.
- Lighting energy standards for all federal buildings were mandated.

Energy Planning

The government also promotes energy-efficient lighting through its broader energy planning activities. The USDOE conducts periodic detailed statistical surveys of commercial and residential buildings. These surveys provide unique information on lighting equipment and energy use across the country (EIA 1992). Government energy demand forecasting and conservation potential projects pay detailed attention to lighting.

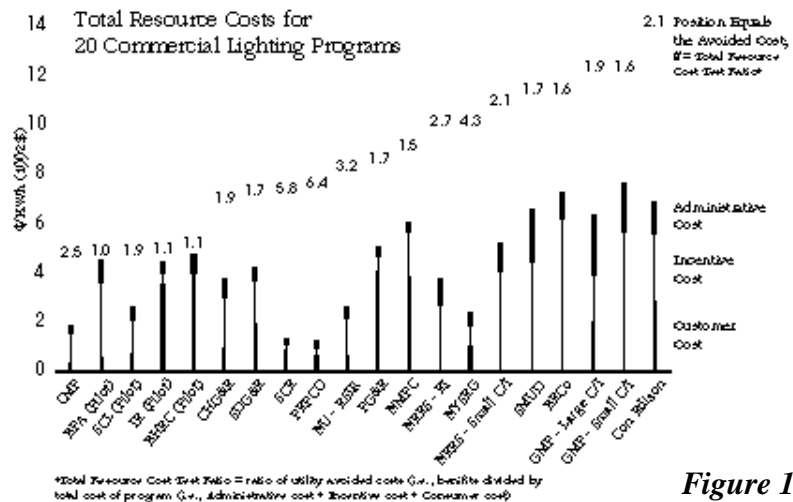


Figure 12

The government also plays a critical role in supporting electric utility conservation efforts in the U.S. and throughout the world. It provides independent evaluation and comparison of various program strategies, (see Figure 12) and technical support to help utilities evaluate which technologies to promote (Mills 1993; Eto et al., 1994). One recent example is the USDOE and EPA's support of the Consortium for Energy Efficiency. CEE has launched the first national rebate program for compact fluorescent lamps based on a manufacturer instead of a consumer rebate and a detailed point system to determine which products are awarded the rebates (Granda 1995).

Information and Technical Assistance

The USDOE co-funded the creation of the Advanced Lighting Guidelines. The publication presents independent information on state-of-the-art efficient lighting technology and design practices (USDOE 1993). With support from the USDOE and the Environmental Protection Agency, the Lighting Research Center (at Rensselaer Polytechnic University in New York) has established a variety of lighting information activities.

The U.S. Environmental Protection Agency's Office of Air and Radiation and the USDOE's Office of Building Technologies fund the National Lighting Product Information Program, operated by the Lighting Research Center of Rensselaer Polytechnic Institute, Troy, New York. The program generates Specifier Reports, which provide testing results for the manufacturers of one technology in each issue. The publications are distributed to participants of EPA's Green Lights program and other groups. Another publication series, Lighting Answers, provides generic information about specific technologies and applications, e.g. task lighting for offices, in question-and-answer format. The project advisory board is drawn from State governments and electric utilities. A new EPA-funded publication from LRC, Lighting Futures, is a quarterly news digest reporting on new technologies and experts' opinions about their likely applications and market potential.

The Lighting Transformations program is a proposed LRC activity that anticipates support from the USEPA and the New York State Energy Research and Development Authority. The program would develop projects focusing on specific technologies (e.g., office lighting, exit signs, HID dimming systems, task lighting for offices, halogen lamps, and residential technologies). Specifications and market research conducted under the program would support the implementation of EPA's Energy Star Program. Lighting Transformations' main objective is to characterize existing markets for efficient lighting technologies and to identify ways of motivating manufacturers to innovate faster, for example, with the assistance of model performance specifications.

The government also provides support for energy auditing around the U.S. DOE created the Energy Analysis and Diagnostic Center (EADC) program in the late 1970s to fund university-based centers to perform energy audits for small- and medium-sized industrial facilities throughout the country. The program has conducted more than 5000 such audits, which include lighting (Belcher and Liu 1995).

The EPA has been running the well-known "Green Lights" program for commercial buildings since the early 1990s. The program is based on a Memorandum of Understanding signed by large building owners. Companies commit to implement all cost-effective retrofits within a 5-year period. Already, about 10% of all U.S. commercial floor space is committed to the program. Future efforts will address residential buildings. The program also awards labels to efficient lighting products; manufacturers use the labels extensively in their advertising materials.

Conclusions

In the U.S., market forces have not succeeded in sufficiently stimulating economically beneficial investments in efficient lighting technologies and practices. Even a major free-market economy like the United States has seen the need to direct significant government involvement towards promoting energy efficient lighting. The methods range from simple information to sophisticated research and development. Russia is another country with substantial lighting energy use, and considerable potential for improved energy efficiency (Aizenberg 1993). In light of the U.S. experience, it is unfortunate to see the former Soviet Union's commitment to R&D decline so rapidly in recent years.

In the U.S., we have found that government can lead the way by example—by making its *own* buildings efficient—and help industries open new markets by providing the high-risk R&D.

References

- Aizenberg, J. 1993. "Energy-saving Lighting in Russia." *Proceedings of the Second European Conference on Energy-Efficient Lighting*, published by NSVV, Arnhem, The Netherlands, pp. 187-195.
- Atkinson, B., J. McMahon, E. Mills, P. Chan, T. Chan, J. Eto, J. Jennings, J. Koomey, K. Lo, M. Lecar, L. Price, F. Rubinstein, O. Sezgen, T. Wenzel. 1992. *Analysis of Federal Policy Options for Improving U.S. Lighting Energy Efficiency: Commercial and Residential Buildings*. Lawrence Berkeley Laboratory Report No. 31469.
- Belcher, C. and L. Liu. 1995. "Willingness to Invest in Lighting Energy Reduction in Industrial Buildings." *Proceedings of the 3rd European Conference on Energy-Efficient Lighting* (forthcoming).
- Berman, S.M.. 1992. "Energy Efficiency Consequences of Scotopic Sensitivity," *Journal of the Illuminating Engineering Society* (Winter).
- Energy Information Administration. 1992. "Lighting in Commercial Buildings," U.S. Department of Energy Report DOE/EIA-0555(92)/1.
- Eto, J. E. Vine, L. Shown, R. Sonnenblick, and C. Payne. 1994. "The Cost and Performance of Utility Commercial Lighting Programs." Lawrence Berkeley Laboratory Report No. 34967.
- Finlayson, E.U., D. K. Arasteh, C. Huizenga, M.D. Rubin, and M.S. Reilly. 1993. "WINDOW 4.0: Documentation of Calculation Procedures," LBL Report No. 33943.
- Granda, C. 1995. "The Consortium for Energy Efficiency Residential Lighting Program," *Proceedings of the 3rd European Conference on Energy-Efficient Lighting* (forthcoming).
- Greenberg, S., E. Mills, D. Lockhart, D. Sartor, W. Lintner. 1994. "The U.S. Department of Energy's In-House Energy Management Program: Meeting the Challenges of Federal Energy Management," *Proceedings of the 1994 ACEEE Summer Study on Energy Efficiency in Buildings*.

- Mills, E. 1993. "Efficient Lighting Programs in Europe: Cost-Effectiveness, Consumer Response, and Market Dynamics," *Energy—The International Journal*, **18**(2), pp. 131-144.
- Ritschard, R.L., C.A. Goldman, E. Vine, E. Mills, and K.M. Greely. 1986. "Cutting Energy Costs in Public Housing: Technical Issues, Institutional Barriers, and Research Needs," Lawrence Berkeley Laboratory Report No. 19683.
- Rubinstein, F. and R. Verderber. 1990. "Automatic Lighting Controls Demonstration", Customer Systems Report Number. 008.1.80-24, Pacific Gas and Electric Company, San Francisco, CA.
- Selkowitz, S., J.J. Kim, M. Navvab, and F. Winkelmann. 1982. "The DOE-2 and SUPERLITE Daylighting Programs," *Proceedings of the 7th National Passive Solar Conference*, International Solar Energy Society.
- Siminovitch, M.J., F.M. Rubinstein and R. E. Whiteman. 1990. "Thermal Performance Characteristics of Compact Fluorescent Fixtures," *Proceedings of the IEEE-IAS Annual Conference*, Seattle, WA.
- Siminovitch, M.J. 1994. "Centralized Lighting Systems for Interior Lighting," *Svetotekhnika*, No. 5, pp 11-12.
- US Department of Energy. 1993. *Advanced Lighting Guidelines*. DOE Report DOE/EE-0008.
- Verderber, R., S. Selkowitz, and S. Berman. 1979. "Energy Efficiency and Performance of Solid-State Ballasts," *Lighting Design & Application*, pp. 23-28.
- Verderber, R., O.C. Morse, A.A. Arthur, and F. Rubinstein. 1982. "Energy Savings with Solid-State Ballasts in a Veterans Administration Medical Center," *IEEE Transactions on Industry Applications*, Vol. IA-18, No. 6, pp. 653-65.
- Ward, G. 1994. "The Radiance Lighting Simulation and Rendering System," *Computer Graphics*, Association for Computing Machinery.